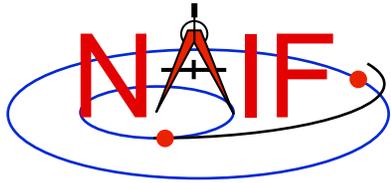


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Navigation and Ancillary Information Facility

# Planetary Constants Kernel PCK

January 2012

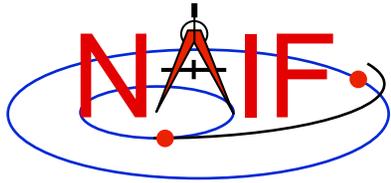


# Topics

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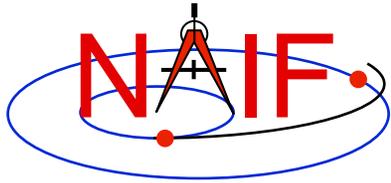
- **Overview**
- **Using PCKs**
- **Text PCKs**
  - IAU Models
- **Binary PCKs**
- **Interface Routines**
- **PCK Reference Frames**



# Overview

## Navigation and Ancillary Information Facility

- **The Planetary Constants Kernel (PCK or Pck) is a component of the logical “planet kernel.”**
  - As implemented in SPICE, PCKs are distinct from the planet ephemeris information provided in SPKs.
- **The PCK subsystem supports text and binary PCK file formats.**
  - Usually text PCK data consist of:
    - » **Orientation (also known as “rotation”) models for extended, natural solar system bodies: sun, planets, natural satellites, a few asteroids**
      - Location of the pole and prime meridian
      - Axis directions of a body-fixed, body-centered reference frame
      - Spin rate
    - » **Physical and cartographic constants**
      - Sets of radii for triaxial shape models.
      - Additional items could be included, such as
        - prime meridian offset from the principal axis
        - magnetic dipole location
        - gravity parameters: GM, J2, higher order gravity field terms
        - ring model parameters
  - **Binary PCKs are used only for high-accuracy orientation data.**
    - » At NAIF, binary PCKs are available only for the earth and the moon.

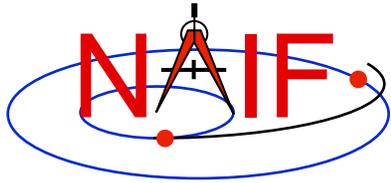


# Text PCKs - 1

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- **Text PCK files contain orientation, shape and other data associated with natural solar system bodies.**
- **NAIF creates and distributes a “generic” text PCK based on the latest IAU/IAG Report.\***
  - The reports are issued about once every three years, and so might not contain the very latest available results.
  - SPICE PCK software is designed to use these data to compute orientation of body-fixed frames.
  - These frames have a name style of “IAU\_*body-name*”
- **NAIF also provides a “masses” PCK, containing GM values for the Sun and planetary systems.**
  - Values from this file are typically used with SPICE osculating element routines, and in using the MAKSPK application to make a Type 5 SPK file.
- **Text PCKs are sometimes produced by flight projects and others—not only by NAIF.**

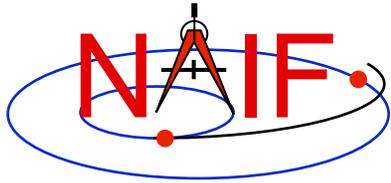
\* “Report of the IAU/IAG Working Group on cartographic coordinates and rotational elements: <year issued>”; published in *Celestial Mechanics and Dynamical Astronomy*



## Text PCKs - 2

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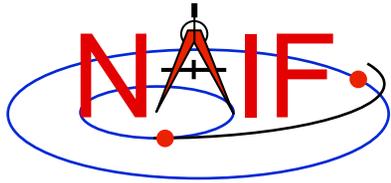
- The **SPICE text** kernel mechanism is used to implement IAU/IAG-based generic PCK files.
  - Users may easily visually inspect data.
  - Users may (carefully!) modify text PCKs with a text editor.
    - » Data or comments may be added, deleted, or changed.
    - » Comments should be added to explain changes.
  - Kernel variables contain the mathematical terms appearing in rotation or shape models. For example:
    - » `BODY699_RADII = ( 60268 60268 54364 )`
    - » `BODY699_POLE_RA = ( 40.589 -0.036 0. )`
    - » `BODY699_POLE_DEC = ( 83.537 -0.004 0. )`
  - The user may include additional kernel variables to change the base frame or reference epoch.
  - Kernel variable names are **case-sensitive**.
    - » NAIF uses only upper case for variable names; we suggest you do the same.



# IAU Orientation Models - 1

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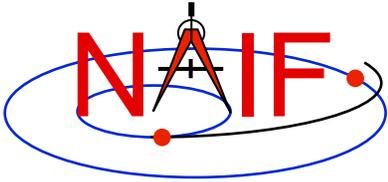
- **SPICE text PCK orientation models use data from the IAU/IAG:**
  - for the sun and planets:
    - » IAU models use low-degree (typically linear) polynomials to represent RA and DEC of the pole (body-fixed +Z-axis) as a function of time.
    - » The prime meridian is also represented by a low-degree polynomial.
    - » Trigonometric polynomial terms are supported by SPICE
      - but are rarely used in IAU models for planet orientation
  - for natural satellites:
    - » Additional trigonometric polynomial terms are used to more accurately represent precession and nutation.
    - » A few satellites exhibit chaotic rotation and so are not modeled.
  - for some major asteroids (e.g. Ida, Eros, Gaspra, Vesta)



# IAU Orientation Models - 2

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- **IAU body-fixed frames are planetocentric. For planets and satellites:**
  - Z-axis is aligned with +/- spin axis. The positive Z-axis points toward the north side of the “invariable plane of the solar system.”
  - The “invariable plane” is normal to the solar system’s angular momentum vector. It is:
    - » approximately the same as Jupiter’s orbital plane.
    - » roughly parallel to the ecliptic plane.
  - X-axis defines the prime meridian.
  - Y-axis completes the right-handed frame.
- **The IAU chooses as its base frame the International Celestial Reference Frame (ICRF), as defined by the International Earth Rotation Service (IERS).**
  - **For historical and backwards compatibility reasons SPICE uses the names “J2000” and “EME2000” as synonyms for the ICRF inertial reference frame, even though J2000 and ICRF are, in fact, not identical. (The difference is “well under 0.1 arc seconds.”)**
- **The IAU reference epoch for rotational models is 2000 Jan 1 12:00:00 TDB, frequently referred to as “J2000.”**
  - **Note: This use of “J2000” is to identify an epoch in time, and should NOT be confused with “J2000” used in SPICE and elsewhere to refer to the ICRF inertial reference frame.**

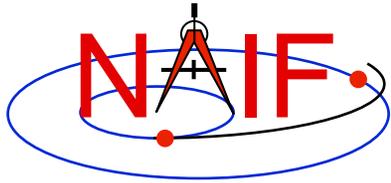


# IAU Shape Models

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- **SPICE text PCK shape models use data from the IAU/IAG**
- **IAU shape models are nominally triaxial ellipsoids**
  - For many bodies, two of the axes (equatorial axes) have the same value (spheroidal)
  - For some bodies, one or more radii have not been determined.
- **Although many bodies are in fact modeled as spheres or spheroids, SPICE deals with the general, triaxial case.**
  - Exception: SPICE supports geodetic coordinate transformations only for bodies modeled as spheres or spheroids.
    - » RECGEO and GEOREC are the modules performing these transformations.
  - Exception: SPICE supports planetographic coordinate transformations only for bodies modeled as spheres or spheroids.
    - » PGRREC, RECPGR, DPGRDR and DRDPGR are the modules supporting these transformations.

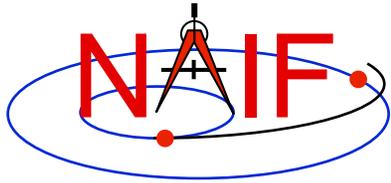


# Special Case: Binary PCKs

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- **The SPICE system stores high-accuracy orientation models in binary PCKs.**
  - Binary PCKs are implemented using the DAF file architecture (as are SPK files)
  - SPICE Toolkit utilities enable reading and writing comments, summarizing, and porting binary PCKs.
  - Like SPK files, binary PCKs support multiple data representations (“data types”).
    - » Type 2: Chebyshev polynomials for Euler angles, angular velocity obtained by differentiation, constant interval length.
    - » Type 3: Separate Chebyshev polynomials for Euler angles and their derivatives, variable interval length.
- **Binary PCKs are limited to storing orientation data.**
  - Applications that require shape data must also load a text PCK.
- **Orientation data from a binary PCK always supersede orientation data (for the same object) obtained from a text PCK, no matter the order in which the kernels are loaded**
- **Binary PCKs are available for the Earth and Moon.**
  - The orientation data provided by these kernels are much more accurate than those provided by generic text PCKs based on the IAU/IAG reports.
  - These kernels are the topic of a tutorial on high-accuracy orientation data and associated frames for the Earth and Moon.

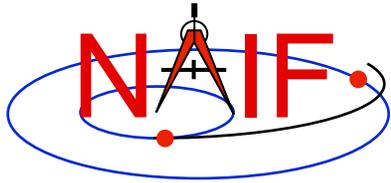


# PCK Reference Frames

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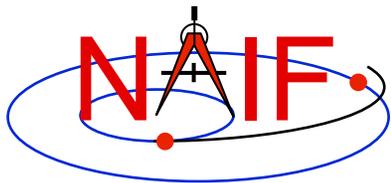
- **Many PCK reference frame specifications are built-in to SPICE.**
  - Just load PCK files to use these frames. Examples:
    - » IAU frames: IAU\_SATURN, IAU\_TITAN, IAU\_EARTH, IAU\_MOON, etc.
    - » IERS frames: ITRF93
- **Other PCK frames are not built in and must be specified at run time by loading frame kernels, for example:**
  - **Body fixed frames for asteroids or “newer” natural satellites**
    - » See the Frames Required Reading technical reference for information on creating frame kernels that specify PCK reference frames.
  - **Lunar body-fixed frames: MOON\_ME, MOON\_PA**
    - » See the tutorial on “high-accuracy” orientation data and associated frames for the Earth and Moon” for details.
- **SPICE makes default associations between bodies and built-in PCK frames**
  - For example, the default PCK frames for the planets are IAU\_MERCURY, IAU\_VENUS, IAU\_EARTH, etc.
  - You can look up the default PCK frame associated with a body by calling CNMFRM or CIDFRM.



# Using PCKs

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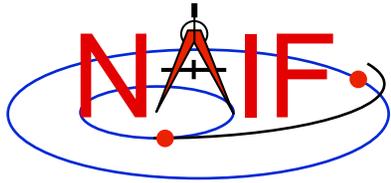
- Load PCKs using FURNISH
- PCK orientation data are usually accessed via Frame system or SPK calls
  - Example: Get the IAU\_SATURN body-fixed reference frame to J2000 position or state transformation matrix at ET:
    - » CALL PIFORM ( 'IAU\_SATURN', 'J2000', ET, RMAT )
    - » CALL SXFORM ( 'IAU\_SATURN', 'J2000', ET, XFORM )
  - Example: Get state of Saturn relative to Cassini in the IAU\_SATURN body-fixed reference frame:
    - » CALL SPKEZR ( 'SATURN', ET, 'IAU\_SATURN', 'LT+S', 'CASSINI', STATE, LT )
  - Example: Get state of Cassini relative to the DSN station DSS-13 in the J2000 inertial reference frame:
    - » CALL SPKEZR ( 'CASSINI', ET, 'J2000', 'LT+S', 'DSS-13', STATE, LT )
      - An Earth PCK **must** be loaded in order for this call to work.
        - Even though the specified reference frame is inertial
        - This call, in the course of its work, converts the position of the DSN station relative to the Earth's center from an Earth-fixed, earth-centered frame to the J2000 frame.
- Access to PCK shape and other data is discussed in the section titled “Interface Routines”



# Interface Routines - 1

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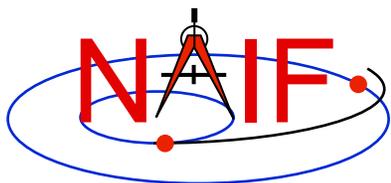
- **Call FURNISH to load PCKs.**
  - CALL UNLOAD or KCLEAR to unload them.
- **Call SXFORM to return a state transformation.**
  - Returns 6x6 matrix (attitude and angular velocity)
    - » CALL SXFORM ( FROM, TO, ET, XFORM )
- **Call PXFORM to return a position transformation.**
  - Returns 3x3 matrix (attitude only)
    - » CALL PXFORM ( FROM, TO, ET, RMAT )
- **Get state of Saturn relative to Cassini in the IAU\_SATURN body-fixed reference frame:**
  - CALL SPKEZR ( 'SATURN', ET, 'IAU\_SATURN', 'LT+S', 'CASSINI', STATE, LT )
- **Get state of Cassini relative to the DSN station DSS-13 in the J2000 inertial reference frame:**
  - CALL SPKEZR ( 'CASSINI', ET, 'J2000', 'LT+S', 'DSS-13', STATE, LT )
    - » **An Earth PCK **must** be loaded in order for this call to work.**
      - Even though the specified reference frame is inertial
      - This call, in the course of its work, converts the position of the DSN station relative to the Earth's center from an Earth-fixed, earth-centered frame to the J2000 frame.



# Interface Routines - 2

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- **Call BODVRD or BODVCD to retrieve constants associated with a body. For example:**
  - `CALL BODVRD ( 'SATURN' , 'RADII' , 3 , N , RADII )`
  - `CALL BODVCD ( 699 , 'RADII' , 3 , N , RADII )`
  - These calls retrieve values associated with the variable BODY699\_RADII.
  - The variable name is **case-sensitive**, so the string “RADII” above must be in upper case.
- **You can use general kernel pool fetch routines to fetch data assigned to any non-standard names**
  - GCPOOL, for character data
  - GDPOOL, for double precision data
  - GIPOOL, for integer data



# PCK Precedence Rules

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- **Orientation data from a binary PCK always supersede orientation data (for the same object) obtained from a text PCK, no matter the order in which the kernels are loaded**
- **In text PCKs, assignments are of two types:**
  - » **“Direct”:** variable name = value(s)
  - » **“Incremental”:** variable name += value(s)
  - **The last direct assignment made to a given variable replaces any/all previous assignments for that variable**
  - **Incremental assignments simply add additional values to an existing variable**
    - » **The variable will be newly created if it didn't already exist**

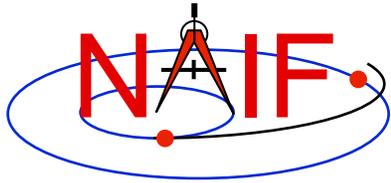


# PCK Utility Programs

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- **The following utility programs included in the Toolkit work with PCKs:**
  - BRIEF** summarizes coverage for one or more binary PCK files
  - SPACIT** generates segment-by-segment summary of a binary PCK file
  - COMMNT** reads, appends, or deletes comments in a binary PCK file
  - FRMDIFF** samples or compares orientation of a PCK-based frame
- **These additional utility programs, provided on the NAIF Web site, also work with PCKs:**
  - DAFMOD** alters frame IDs in a binary PCK file
  - DAFCAT** concatenates together binary PCK files
  - BFF** displays binary file format of an binary PCK file
  - BINGO** converts binary PCK files between big-endian and little-endian formats

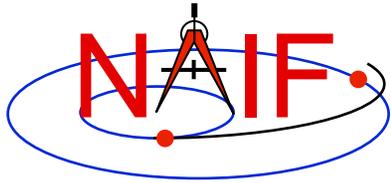


# Additional Information on PCK

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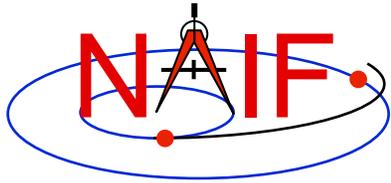
- **For more information about PCKs, look at the following:**
  - Most Useful Routines document
  - PCK Required Reading document
  - Headers of the routines mentioned
  - Lunar/Earth High-Precision PCK/FK tutorial
  - BRIEF and FRMDIFF User's Guides
- **Related documents:**
  - Frames Required Reading
  - Kernel Required Reading
  - NAIF\_IDS Required Reading
  - Time Required Reading



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# Backup



# Changing the Default Frame

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- **Some (mostly deprecated) SPICE routines implicitly use the default PCK frames (IAU\_<body name>).**
- **You can change the default PCK frame associated with a body by loading a frame kernel that assigns a new default frame to that body.**
  - For the Earth or Moon, you can load a “frame association kernel” provided by NAIF.
  - For any body, you can load a frame kernel containing the assignment  
`OBJECT_<body name>_FRAME = '<new default frame name>'`  
» **Example:** `OBJECT_MOON_FRAME = 'MOON_ME'`
- **For high-accuracy work involving the Earth or Moon and any SPICE routines that use the default PCK frames, you normally would override the SPICE default frames by loading frame association kernels.**
  - Reference the tutorial on “high-accuracy” orientation data and associated frames for the Earth and Moon for details.